Electric Field of Line Charge

The electric field of a line of charge can be found by superposing the point charge fields of infinitesmal charge elements. The radial part of the field from a charge element is given by

$$dE_z = \frac{k\lambda dx}{r^2}\frac{z}{r}$$

The integral required to obtain the field expression is

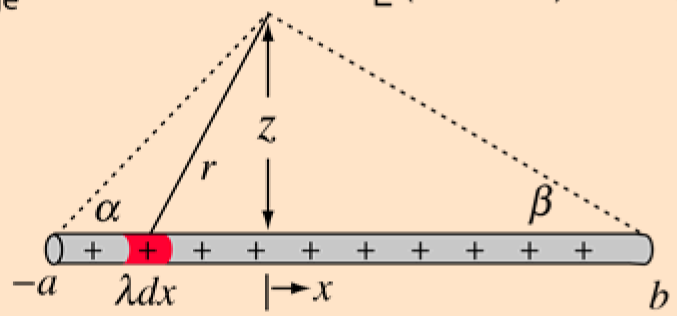
$$E_z = k\lambda z\int_{-a}^{b}\frac{dx}{\left(z^2+x^2\right)^{3/2}} = \frac{k\lambda}{z}\left[\frac{x}{\left(z^2+x^2\right)^{1/2}}\right]_{-a}^{b}$$

$$E_z = \frac{k\lambda}{z}\left[\frac{b}{\left(z^2+b^2\right)^{1/2}} + \frac{a}{\left(z^2+a^2\right)^{1/2}}\right]$$

Note that as the limit is taken as a and b approach infinity, this approaches the infinite line charge expression:

$$E_z = \frac{2k\lambda}{z}$$

$$= \frac{\lambda}{2\pi\varepsilon_0 z}$$



Infinite line charge

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Electric Field: Ring of Charge

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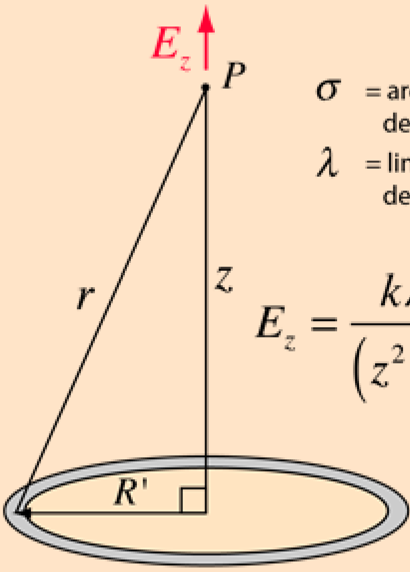
Electric field concepts

The electric field of a ring of charge on the axis of the ring can be found by superposing the point charge fields of infinitesmal charge elements. The ring field can then be used as an element to calculate the electric field of a charged disc.

The electric fields in the xy plane cancel by symmetry, and the z-components from charge elements can be simply added.

$$E_z = \frac{kQ\cos\theta}{r^2} = \frac{kQz}{r^3} = \frac{kQz}{\left(z^2 + R'^2\right)^{3/2}}$$

Q = total charge



σ = area charge density

λ = linear charge density

$$E_z = \frac{k\lambda 2\pi R' z}{\left(z^2 + R'^2\right)^{3/2}}$$

If the charge is characterized by an area density and the ring by an incremental width **dR'** , then:

$$dE_z = \frac{k\sigma 2\pi z R' dR'}{\left(z^2 + R'^2\right)^{3/2}}$$

This is a suitable element for the calculation of the electric field of a charged disc.

Electric potential of a ring of charge

Fields for other charge geometries

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Electric Field:Disc of Charge

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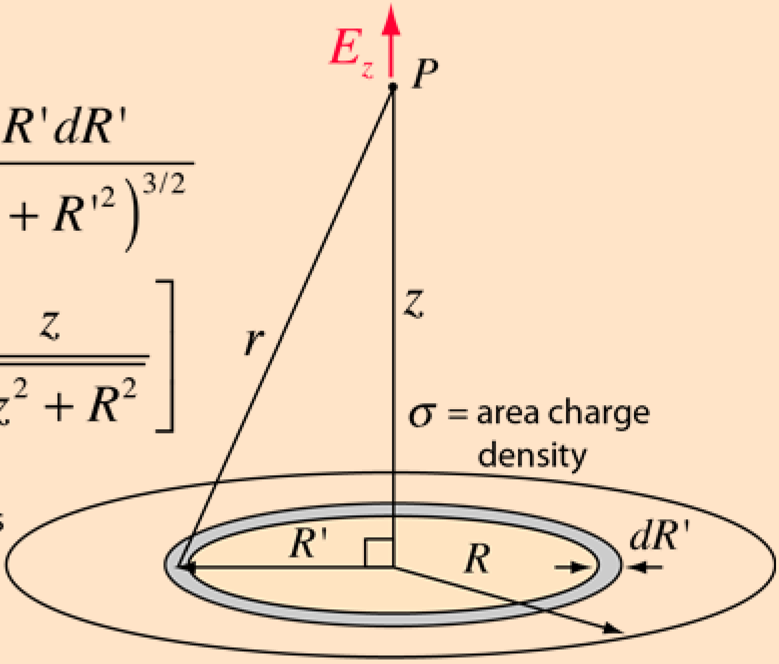
Electric field concepts

The electric field of a disc of charge can be found by superposing the point charge fields of infinitesmal charge elements. This can be facilitated by summing the fields of charged rings. The integral over the charged disc takes the form

$$E_z = k\sigma 2\pi z \int_0^R \frac{R'dR'}{\left(z^2 + R'^2\right)^{3/2}}$$

$$E_z = k\sigma 2\pi \left[1 - \frac{z}{\sqrt{z^2 + R^2}}\right]$$

$$k = \frac{1}{4\pi\varepsilon_0} = \text{Coulomb's constant}$$



[Electric potential of disc of charge]

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